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AIL Type 130

PRECISION TEST RECEIVER

December 1963

CUTLER-HAMMER

AIRBORNE INSTRUMENTS LABORATORY
DEER PARK, LONG ISLAND, NEW YORK

CONTROL AIL DIVISION

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SECTION I
GENERAL DESCRIPTION

A. GENERAL

The AIL Type 130 Precision Test Receiver (Figure 1) is a versatile test instrument combining a high-gain, low-noise-figure receiver with a secondary standard of attenuation. It is capable of operating a wide variety of standard microwave mixers from the IF output; in combination with such mixers and a suitable local oscillator, it is a sensitive detector of microwave energy. The receiver can be used wherever accurate measurement of the differences of RF or IF power levels is required.

Standard models of the Type 130 are provided for either 30 or 60 Mc use unless otherwise noted. The information supplied in this handbook applies to either of the standard models.

B. MAJOR EQUIPMENT AND ACCESSORIES

The receiver consists of an IF preamplifier, followed by a precision attenuator, post-amplifier, and output indicator. A built-in 115-volt 60-cps regulated power supply provides operating voltages for the receiver. The preamplifier portion is packaged in a separate chassis so that it can be conveniently located with respect to the particular microwave mixer application. The remaining portions and the power supply are housed in the main cabinet. Power and IF cables that connect the preamplifier unit to the main receiver cabinet are supplied.

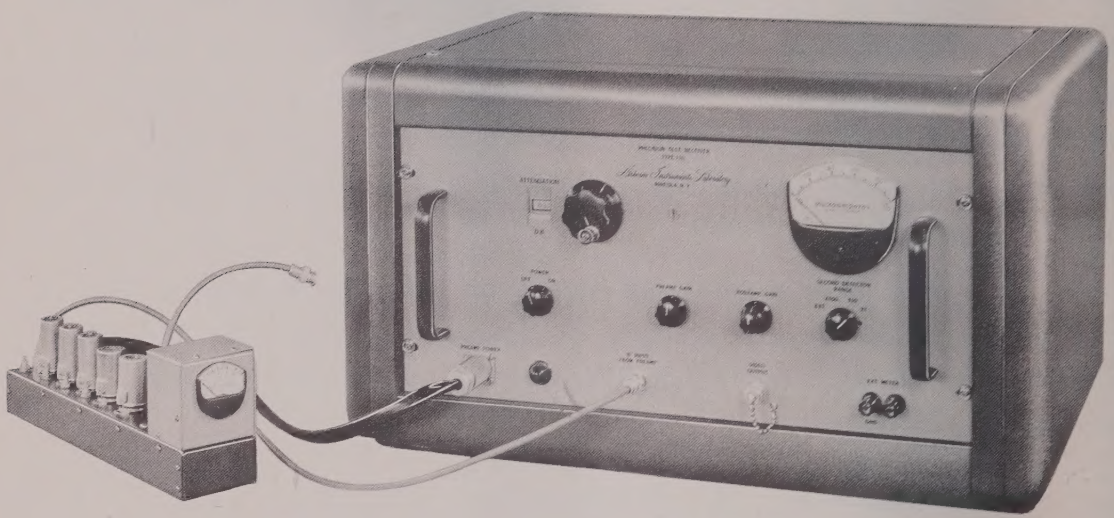

FIGURE 1. AIL TYPE 130 PRECISION TEST RECEIVER

1. IF PREAMPLIFIER*

The 30-Mc IF preamplifier is designed to have a noise figure of about 1.5 db at the design center and better than 2.5 db over a wide range of source resistances and capacitances. The preamplifier output is connected to the precision attenuator in the main receiver cabinet by standard IF cable (RG-55/U).

2. ATTENUATOR

The attenuator installed in the receiver is a standard AIL Type 30 Precision IF Attenuator. This unit provides an attenuation range of 0 to 80 db, above the minimum insertion loss, to an accuracy of $\pm$0.005 db per db of indicated increment.

3. POST-AMPLIFIER

The post-amplifier has a voltage gain greater than 10,000 and is followed by a detector, video amplifier, and cathode follower. A rectified second-detector current meter is provided, as well as a front-panel jack to which an external meter may be connected. The second detector operates in the square-law region for currents of up to about 100 μa. The overall bandwidth of the 30-Mc model is about 2 Mc.

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* Several models of this preamplifier are available. The standard unit is designed for use with single-ended (single crystal) mixers. A second model is available for use with double-ended (two crystals) mixers with unbalanced outputs. In this type of mixer, one of the crystals is of reverse polarity, so that the phases of the IF signals from the two mixer crystals are the same. A third type for use with double-ended balanced mixers can be supplied on special order. In the latter case, a special balanced-to-unbalanced transformer is installed in the input circuit of the preamplifier.

4. POWER SUPPLY

The 115-volt 60-cps power supply is a standard commercial series shunt regulated unit. It delivers DC at 120 volts and AC at 6.3 volts to the preamplifier and post-amplifier.

C. REFERENCE DATA

Nomenclature	AIL Type 130 Precision Test Receiver
Number of Packages per Complete Shipment	One
Shipping Weight	80 pounds
Net Weight	58 pounds
Input Signal Frequency Range	30 or 60 Mc*
Primary Power	115 volts, single phase, 60 cps, 50 watts
Summary of Technical Characteristics	
Bandwidth	2 Mc (approximately)
Source impedance	300 ohms in parallel with 30 pf at design center
Noise figure (30-Mc version)	1.5 db at design center; better than 2.5 db with a source resistance of 300 ohms and a source capacitance varying from 5 to 60 pf; better than 2.5 db with a source capacitance of 30 pf and a source resistance varying from 50 to 900 ohms

* Other frequencies are available on special order.

Attenuation range	Continuously variable over an 80-db attenuation range above the minimum insertion loss
Attenuation accuracy	Indicated attenuation (above minimum insertion loss--counter reading 000), accurate to within ±0.005 db/db

D. EQUIPMENT SUPPLIED

	Quantity
AIL Type 130 Precision Test Receiver (30 or 60 Mc)	1
Main Cabinet	1
Preamplifier Unit (as specified)	1
Interconnecting Cables (complete set)	1

E. TUBE COMPLEMENT

Unit	5847	5842	6136	6AK5	12AT7	5V4-G	6SJ7	6L6-G	6X5-GT	0A3	Total
Preamplifier	1	1	3								5
Post-Amplifier				5	1						6
Power Supply						1	1	2	1	1	6

SECTION II
THEORY OF OPERATION

A. BASIC EQUIPMENT

The Type 130 Precision Test Receiver is basically an amplifier of IF signals that incorporates a precision means of inserting finely controlled amounts of attenuation. The low-noise-figure input circuit of the receiver enables it to be operated in conjunction with a wide variety of standard microwave mixers. The precision attenuation characteristics can therefore be transferred to microwave frequencies. Because of its adaptability and accuracy, the equipment has many laboratory applications, such as measurement of IF gain and loss, RF gain and loss, and microwave receiver noise figure. Figure 2 is a block diagram of the complete receiver.

B. COMMON TEST APPLICATIONS

To show some of the common test applications for which the Type 130 Receiver is used, measurements of gain and noise figure are discussed.

1. GAIN MEASUREMENT

One of the most satisfactory means of making gain (or loss) measurements is by the substitution method. In this method, the device under test is connected into the testing instrument, and the instrument output indication for a given input signal is noted. The device is then disconnected from the instrument, and the original output level is re-established by either of two means: increasing the signal-generator output, or decreasing the attenuation in the test instrument. With the Type 130 Receiver, the use of the attenuation technique is considered preferable for the following reasons:

1. If the device under test is connected directly in series with the attenuator, the entire system is operating at the same signal levels under both conditions of measurement. This eliminates problems caused by nonlinearities in any of the amplifiers associated with the measurement.

2. The attenuators associated with signal generators are not sufficiently precise for many measurements, and their drive systems usually have more backlash than is often allowable. Furthermore, such attenuators must operate over the frequency range of the particular signal generator, thereby introducing frequency errors. The use of a secondary standard of attenuation at a fixed intermediate frequency eliminates these shortcomings.

2. NOISE-FIGURE MEASUREMENT

The noise generator most often used to measure the noise figures of microwave receivers is of the gas-discharge type. Because the output power of such generators is not variable, the ratio of output powers under generator-on and generator-off conditions will vary with the noise figure of the receiver under test. This ratio, termed the Y factor, is rapidly and accurately determined with the precision attenuator in the Type 130 Receiver.

The general formula for deriving the noise figure of a microwave receiver (using a gas-discharge noise source) is as follows:

$$F = \frac{\left(\frac{T_2}{T_o} - 1\right) - Y\left(\frac{T_1}{T_o} - 1\right)}{Y - 1} \qquad (1)$$

where

T_2 = effective temperature of the discharge generator in the "on" condition,

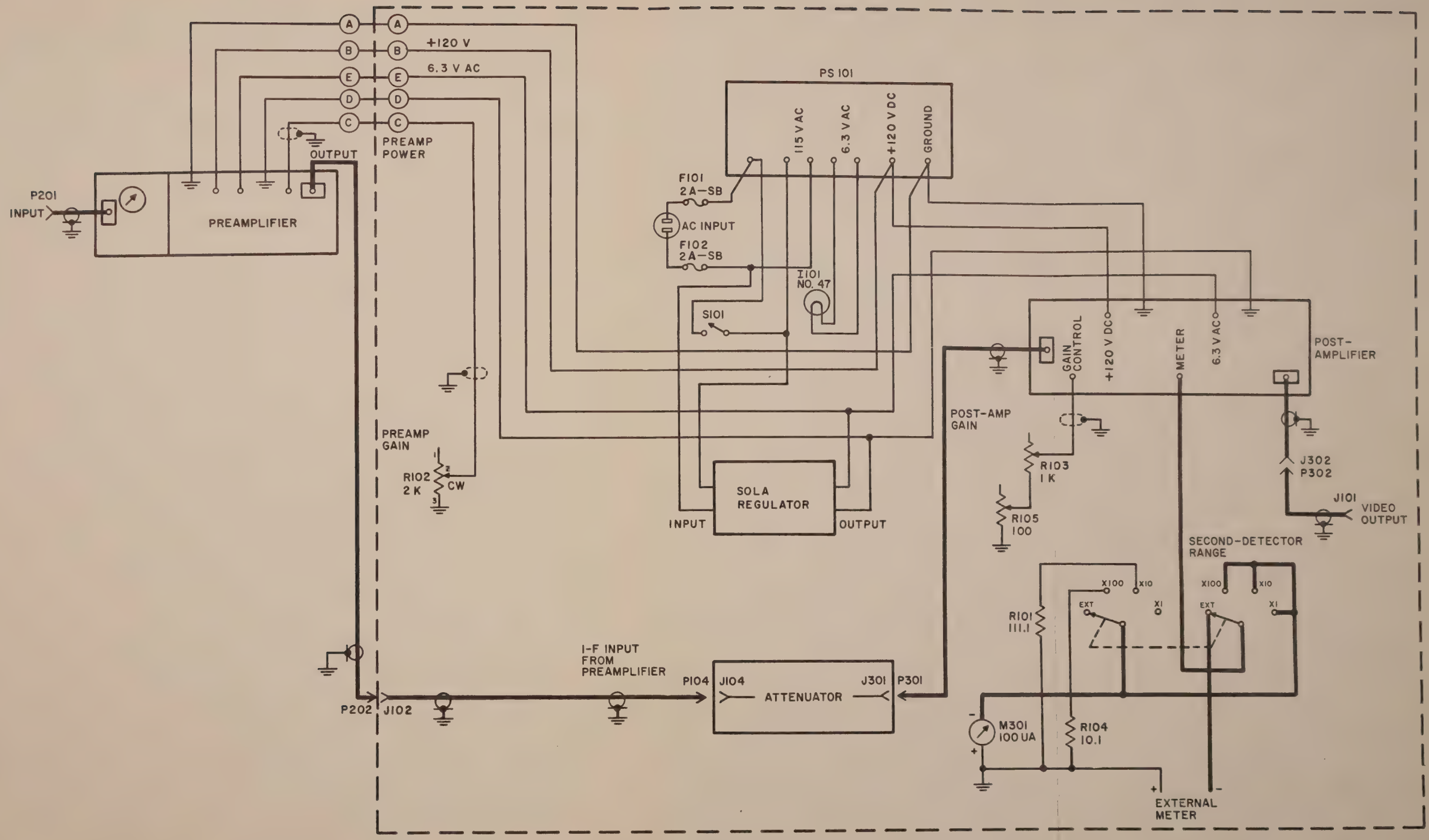


FIGURE 2. BLOCK DIAGRAM OF TYPE 130 PRECISION TEST RECEIVER

T_1 = effective temperature of the discharge generator in the "off" condition,

$T_o = 290^oK$,

Y = ratio of the noise power output of the receiver in the "on" condition to that in the "off" condition; "on" and "off" referring to the condition of the noise source.

In most practical cases, $T_1/T_o \approx 1$, so that the above formula reduces to:

$$F = \frac{\left(\frac{T_2}{T_o} - 1\right)}{Y - 1} \qquad (2)$$

or

$$F_{db} = 10 \log \left(\frac{T_2}{T_o} - 1\right) - 10 \log (Y - 1) \qquad (3)$$

Precise measurements of Y are obtained by means of the precision attenuator in the main console of the Type 130 Receiver. Figure 3 shows several curves plotting noise figure as a function of the value of Y for various types of discharge generators. For reference purposes, some of the commonly used discharge lamps are listed below.

Lamp Type	db above 290^oK	^oK
T5 - 8 w Fluorescent Lamp	15.85	11,400
Roger White - All Generators	18.0	18,600
Philco L1306 Bendix TD10 Bendix TD11 Bendix TD12	15.28	10,100

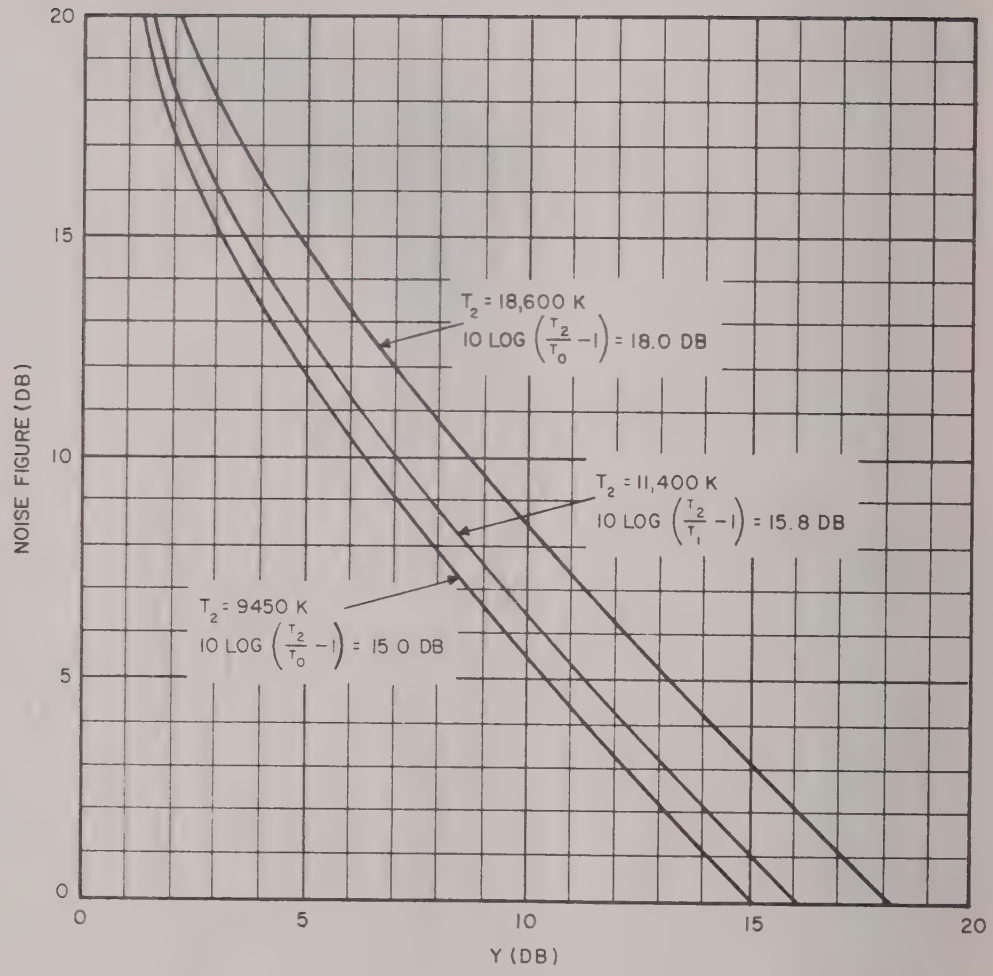


FIGURE 3. NOISE FIGURE AS A FUNCTION OF Y FOR VARIOUS DISCHARGE GENERATORS

C. FUNCTIONAL DESCRIPTION OF UNITS

1. PREAMPLIFIER

The preamplifier circuit, as shown in Figure 4, is designed to operate from a single-ended mixer. It is a low-noise cascode input circuit that represents the most efficient type of preamplifier input-circuit design. L204 series-resonates with the input capacitance of V201 and, functioning as a simple series transformer, steps up the resistive component of the mixer impedance to that required for optimum noise figure of the cascode. The use of a type 5847 as an input tube is dictated by two considerations:

1. This tube has an extremely low equivalent noise resistance,
2. The impedance (looking back from its grid) for optimum noise figure is low.

This latter condition means that a low step-up ratio from input to grid can be used, resulting in relative insensitivity to impedance variations. It is extremely important that L204 have low losses because any such loss adds directly to the noise figure of the preamplifier. L204 and other input-circuit components are contained in a separate compartment of the preamplifier. The coil is carefully oriented to control coupling with other components and is space-wound on a form that has a large diameter. Under these conditions, the Q of L204 averages about 250. The remainder of the cascode is conventional and has been well described in the literature.

The remaining portion of the preamplifier circuit consists of three stages of single-tuned amplification (V203, V204, and V205), the final plate circuit being a series-resonant step-down transformer leading to the output cable. R209 (39 ohms), in series with the losses in L219, causes the output impedance of the preamplifier to be approximately

50 ohms. The gain of the preamplifier is controlled in the last three stages by increasing the cathode bias resistance, thereby reducing the amount of current in the tubes and, hence, the transconductance.

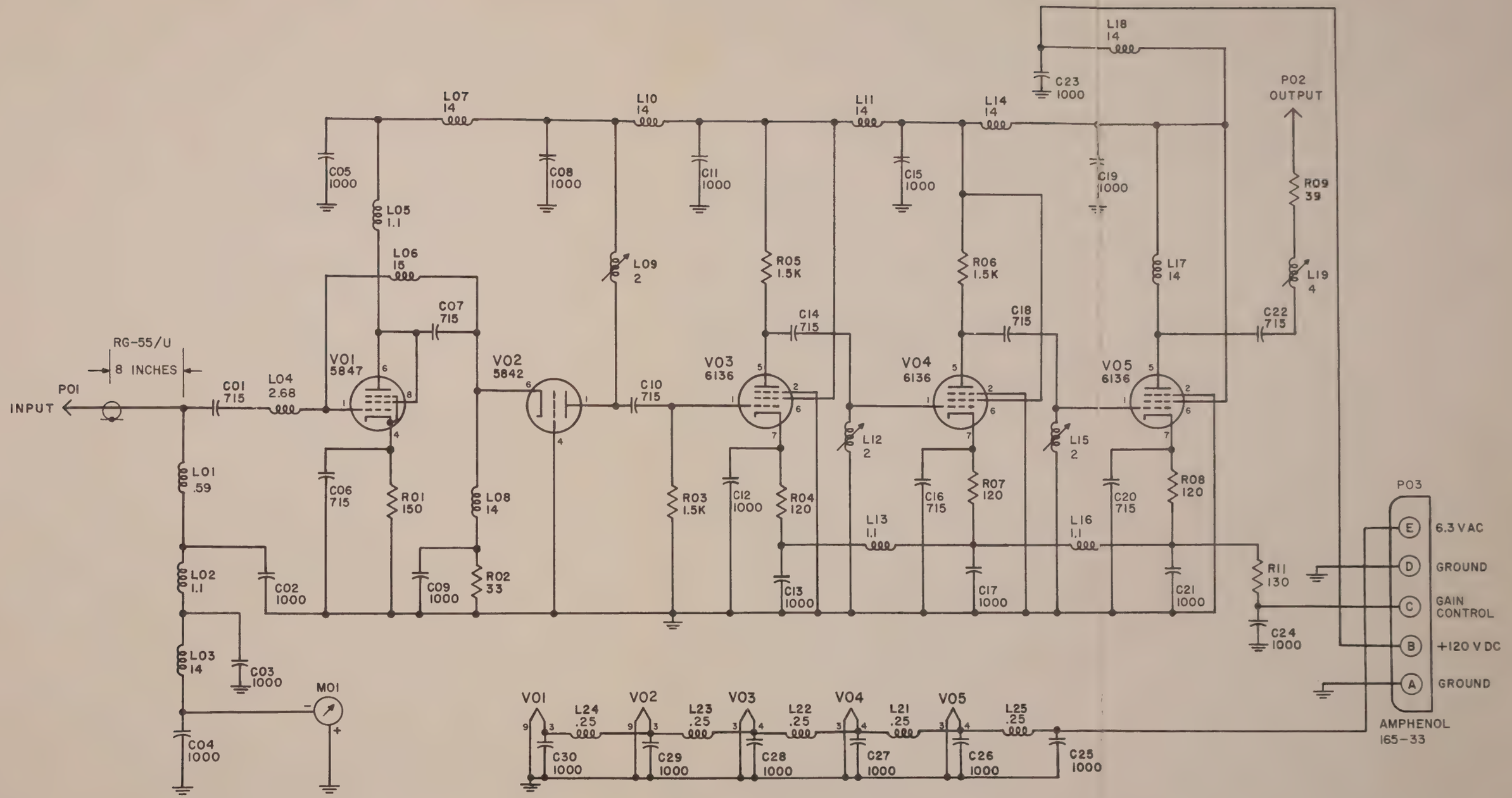
Crystal current is measured by M201, a 1-ma meter located on the front panel of the preamplifier. It should be noted that a small crystal bias may be present as a result of the meter resistance being in series with the crystal.

2. IF ATTENUATOR

The IF attenuator is of the waveguide-beyond-cutoff type. The amount of attenuation is determined by the spacing between the input and output loops and by the diameter of the circular waveguide in which the loops are mounted. The dimensions of the guide are held to very close tolerances during manufacture, as is the mechanical drive system controlling the loop spacing. Minimum spacing between the loops is adjusted so that the coupling is achieved solely by means of the evanescent mode of propagation, and the linearity of the attenuator as a function of the loop spacing is ensured.

The law of the attenuator (attenuation versus loop spacing) is practically independent of frequency, since the waveguide is well below cutoff. The insertion loss of the attenuator, however, varies with frequency, and care must be taken in making gain measurements as a function of intermediate frequency. The dial reading of the attenuator setting is not to be taken as a measure of the total insertion loss. The difference between two readings at any frequency in the specified band ($\pm$16 percent of the design center frequency) is, however, a direct measure of the change in gain or loss to an accuracy of $\pm$0.005 db/db.

The input and output coils of the attenuator are each in series with a capacitor and resistor. The series



UNLESS OTHERWISE NOTED:
RESISTOR VALUES ARE GIVEN IN OHMS
CAPACITOR VALUES ARE GIVEN IN UUF
INDUCTOR VALUES ARE GIVEN IN UH
ADD 200 TO ALL COMPONENT REFERENCE NUMBERS

FIGURE 4. SCHEMATIC DIAGRAM OF 30-Mc PREAMPLIFIER

R-L-C circuit is resonated at 30 or 60 Mc, and the Q of the circuit is sufficiently low to restrict the input SWR, within the ±16 percent bandwidth, to less than 1.5.

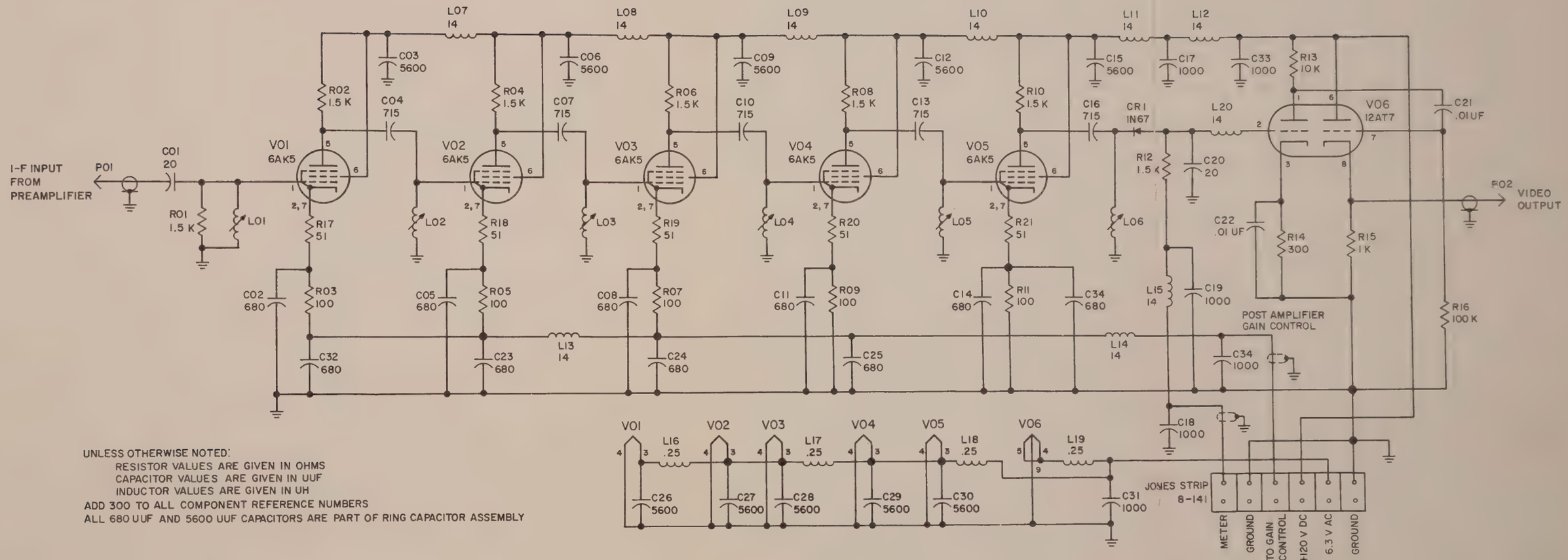
3. POST-AMPLIFIER

The post-amplifier consists of five stages of single-tuned amplification followed by a crystal detector, a video amplifier, and a cathode-follower output. Figure 5 is a schematic diagram of this unit.

The input-circuit components (R301 and L301) present a 50-ohm impedance, and step up the 50-ohm source impedance to approximately 1500 ohms at the grid connection of V301. The amplifier circuit is conventional. CR301, a type 1N67 crystal detector, is used to detect the IF signal. The second-detector current is brought to a meter circuit on the front panel of the receiver. In the most sensitive setting (X1) of the meter scale switch (Figure 2), the input-to-output characteristic of the receiver is practically square law. In the ranges beyond this, operation rapidly approaches a linear law. A single stage of video amplification followed by a cathode follower delivers video signals to video output jack P302. Gain control is achieved, as in the preamplifier, by adding resistance in series with the cathode resistors of the first three stages.

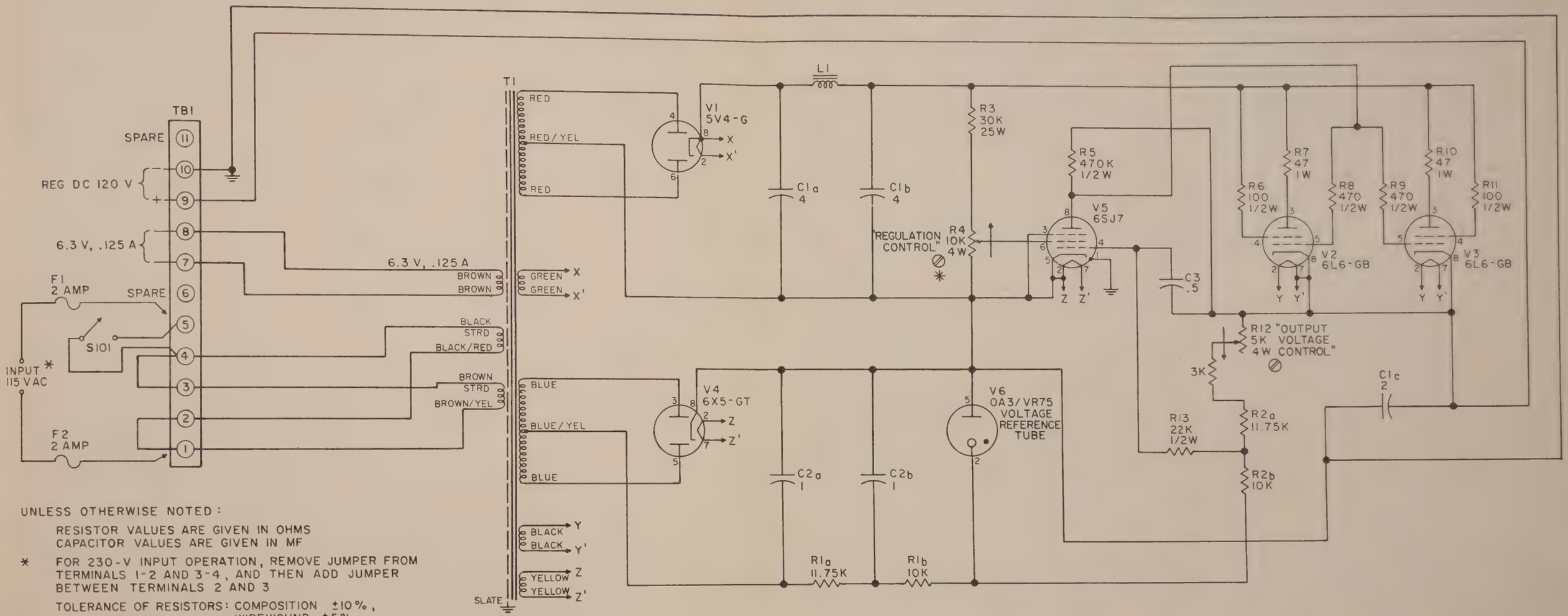
4. POWER SUPPLY

The power supply used to provide operating voltages for all the units in the receiver is a standard series shunt regulated supply. A schematic diagram is shown in Figure 6. A general description of this power supply is given in the appendix.



UNLESS OTHERWISE NOTED:
RESISTOR VALUES ARE GIVEN IN OHMS
CAPACITOR VALUES ARE GIVEN IN UUF
INDUCTOR VALUES ARE GIVEN IN UH
ADD 300 TO ALL COMPONENT REFERENCE NUMBERS
ALL 680 UUF AND 5600 UUF CAPACITORS ARE PART OF RING CAPACITOR ASSEMBLY

FIGURE 5. SCHEMATIC DIAGRAM OF 30-Mc POST-AMPLIFIER



UNLESS OTHERWISE NOTED:

RESISTOR VALUES ARE GIVEN IN OHMS
CAPACITOR VALUES ARE GIVEN IN MF

* FOR 230-V INPUT OPERATION, REMOVE JUMPER FROM TERMINALS 1-2 AND 3-4, AND THEN ADD JUMPER BETWEEN TERMINALS 2 AND 3

TOLERANCE OF RESISTORS: COMPOSITION ±10%, WIREWOUND ±5%
CAPACITORS RATED AT 600 VDC WORKING
TOLERANCE OF CAPACITORS: SINGLE SECTION ±10%; MULTIPLE SECTION -10%, +20%

INDICATES CLOCKWISE ROTATION OF SHAFTS
INDICATES CONNECTION TO CHASSIS
INDICATES SCREWDRIVER SLOT
INDICATES FACTORY ADJUSTMENT - SEE INST. MANUAL

FIGURE 6. SCHEMATIC DIAGRAM OF POWER SUPPLY

SECTION III
OPERATING INSTRUCTIONS

A. OPERATING CONTROLS

All of the operating controls for the Type 130 Receiver are described in Table I.

TABLE I
OPERATING CONTROLS

Control	Type	Function
POWER	Two-position rotary switch	Controls primary power to all units of the receiver
PREAMP GAIN	Variable resistor	Changes cathode bias resistance of last three stages of pre-amplifier
POSTAMP GAIN	Variable resistor	Changes cathode bias resistance of first three stages of post-amplifier
SECOND DETECTOR RANGE	Four-position rotary switch	Changes shunts on meter indicator
ATTENUATION DB	Rotary crank	Varies distance between coupling loops in a waveguide-beyond-cutoff attenuator

B. PREPARATION FOR USE

1. PHYSICAL CHECK

Though the subject equipment is shipped ready for use, it should be carefully inspected for any evidence of damage that may have occurred in shipment. Check especially for loose tubes in sockets, loose wires and connections, or cracked meter faces.

2. INITIAL ADJUSTMENT

To place the Type 130 Receiver in operation:

1. Connect the coaxial cable between the IF preamplifier and the IF INPUT jack on the front panel of the main cabinet.
2. Connect the power cable from the IF preamplifier to the PREAMP POWER jack on the front panel of the main cabinet.
3. Connect the preamplifier input cable to the mixer under test.
4. Connect the AC line cord from the main cabinet to a source of 110-volt 60-cps AC power.
5. With both the PREAMP and the POSTAMP GAIN controls fully counterclockwise, turn the POWER switch to the ON position, and allow one minute for warmup.

C. OPERATIONAL USE

The paragraphs that follow give instructions for the use of the Type 130 Receiver in several types of test applications. These particular applications were chosen to demonstrate the versatility of the equipment. However, the receiver is obviously not restricted to these measurements alone. For example, measurements of SWR, coupler characteristics, and selectivity characteristics are other possible applications.

1. GAIN OR LOSS MEASUREMENT

To measure IF gain, set the attenuator to 000. The equipment is set up as shown in Figure 7, with the preamplifier connected directly to the attenuator (or between the pads, if used).

If the device to be measured is critical with regard to source and output impedance, it is desirable to pad the output of the preamplifier and the input to the attenuator with a carefully matched 6- or 10-db pad.

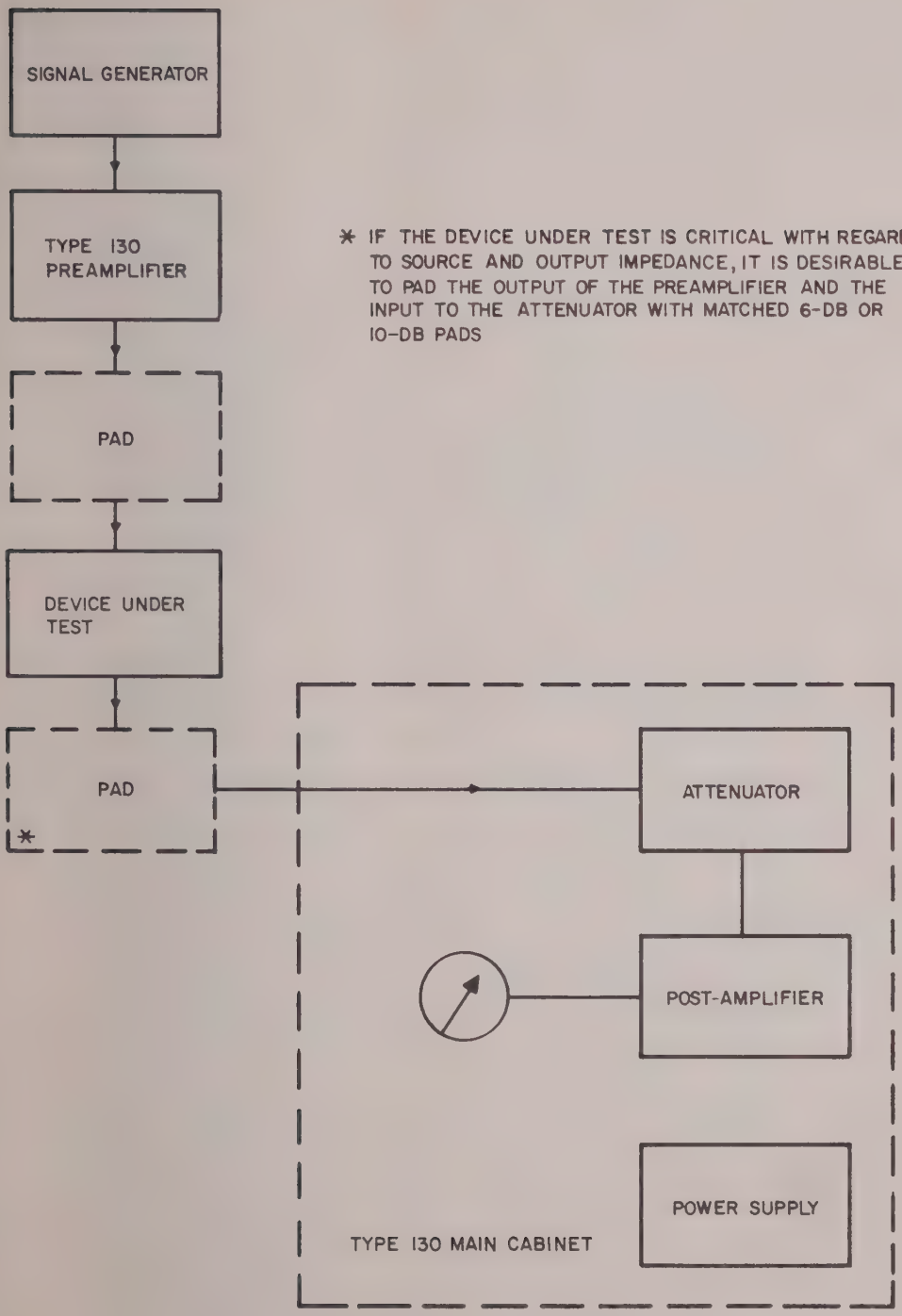

SIGNAL GENERATOR
TYPE 130 PREAMPLIFIER
PAD
DEVICE UNDER TEST
PAD
*
* IF THE DEVICE UNDER TEST IS CRITICAL WITH REGARD TO SOURCE AND OUTPUT IMPEDANCE, IT IS DESIRABLE TO PAD THE OUTPUT OF THE PREAMPLIFIER AND THE INPUT TO THE ATTENUATOR WITH MATCHED 6-DB OR 10-DB PADS
ATTENUATOR
POST-AMPLIFIER
POWER SUPPLY
TYPE 130 MAIN CABINET

FIGURE 7. TEST SETUP FOR MEASUREMENT OF IF GAIN OR LOSS

Adjust the signal output so that the signal level is about 10 times the noise level on the X1 setting of the front-panel meter (M301). Set the noise level by adjusting the PREAMP or POSTAMP GAIN controls; set the signal level by adjusting the signal-generator output.

If the device to be measured is connected as described above, the relative setting of the gain controls is unimportant. It should also be noted that, in many cases, the preamplifier is unnecessary. This is always true when the device to be measured has a net gain rather than loss, or when the signal-generator output is large. When the full range of the attenuator is to be utilized, it is essential that the device to be measured be connected between the preamplifier and the main cabinet, and not ahead of the preamplifier.

Connect the device to be measured between the preamplifier and the attenuator (between the pads, if used). Adjust the attenuator with the crank control to re-establish the original output. The ATTENUATION dial then reads the gain.

To measure IF loss, set the attenuator to 000. The setup is as shown in Figure 7, with the device under test connected between the preamplifier on the attenuator (or between the pads, if used).

Adjust the signal output so that the signal level is about 10 times the noise level on the X1 setting of the front-panel meter (M301). Set the noise level by adjusting the PREAMP or POSTAMP GAIN controls; set the signal level by adjusting the signal-generator output.

Remove the device under test, and connect the preamplifier directly to the attenuator (or between the pads, if used).

Adjust the attenuator with the crank control to re-establish the original output. The ATTENUATION dial then reads the loss.

To measure RF gain and loss, use the test setup shown in Figure 8 and proceed as before for gain or loss measurements.

NOTE

Since the device to be measured is not immediately adjacent to the attenuator, or connected to it through linear passive pads, the linearity of the mixer and preamplifier will affect the accuracy of the measurement.

The following precautions must be observed to ensure that the full accuracy of the attenuator is used.

1. The signal level at the mixer must not exceed 10 percent of the local-oscillator power absorbed in the mixer itself.
2. The preamplifier is linear for signals up to 50 db above noise with the PREAMP GAIN control in the fully counterclockwise position (minimum gain). If the minimum signal-to-noise ratio used is 10:1, the range of signals wherein the preamplifier does not affect the accuracy of the attenuator is from 10 to 50 db above noise. If the device to be measured has a gain or loss greater than 40 db, the recommended procedure is as follows.

RF pads of less than 40 db may be calibrated using the attenuator in the Type 130 Receiver and observing the above precautions. These pads, together with the attenuator, may be used to "build up" any value of attenuation desired.

For example, a device whose loss is about 65 db would be measured as follows. A group of pads would be calibrated with the attenuator in the Type 130 Receiver. Assume

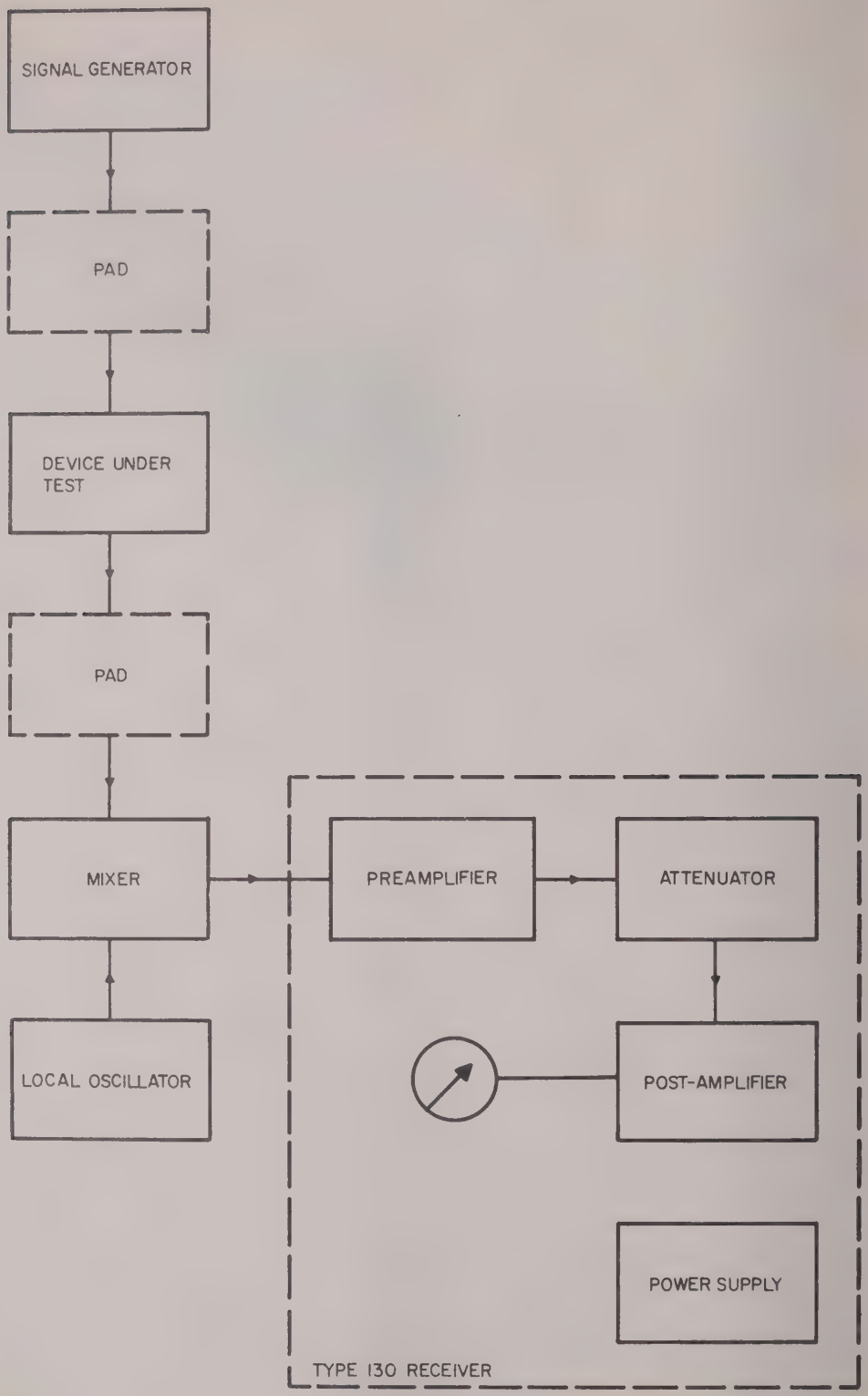


FIGURE 8. TEST SETUP FOR MEASUREMENT OF RF GAIN OR LOSS

that these pads have attenuations of 22.3, 18.7, and 21.0 db. With the device connected in the measurement setup as in Figure 8, the initial conditions are established in the standard manner. The device is removed, and the calibrated pads are substituted for it. The attenuator is adjusted to re-establish the initial conditions. If the reading of the attenuator is less than 40 db, then the proper precautions have been observed. The attenuation of the device is then the sum of the pads plus the attenuator setting. Assuming that the attenuator reads 5.8 db, the device would have a loss of 67.8 db (or 22.3 + 18.7 + 21.0 + 5.8). In this method, the attenuator setting must be less than 40 db if the preamplifier linearity is not to affect the accuracy of the reading.

2. NOISE-FIGURE MEASUREMENT

As mentioned in paragraph C-2, the noise figure is best measured through the Y-factor technique. This Y-factor is conveniently and accurately measured with the Type 130 Receiver by the following method:

1. Connect the device to be measured as shown in Figure 9.
2. With the noise generator off, and the mixer terminated in a Z_o load, set the gain controls to give a convenient output--about mid-scale on the meter. Set the PREAMP GAIN at the maximum (fully clockwise) position, and adjust the POSTAMP control to give this output with the ATTENUATION dial reading 000.
3. Turn the noise generator on, and adjust the ATTENUATION dial to return the output to its initial value. The Y-factor is the attenuator reading. The noise figure can then be determined from Figure 2 for the particular noise generator used.
4. If a variable-output-power noise generator is used (such as a noise diode), it is convenient to use a Y-factor of 2:1 (3 db). In this case, repeat steps 1 änd 2 above. In step 3, set the attenuator

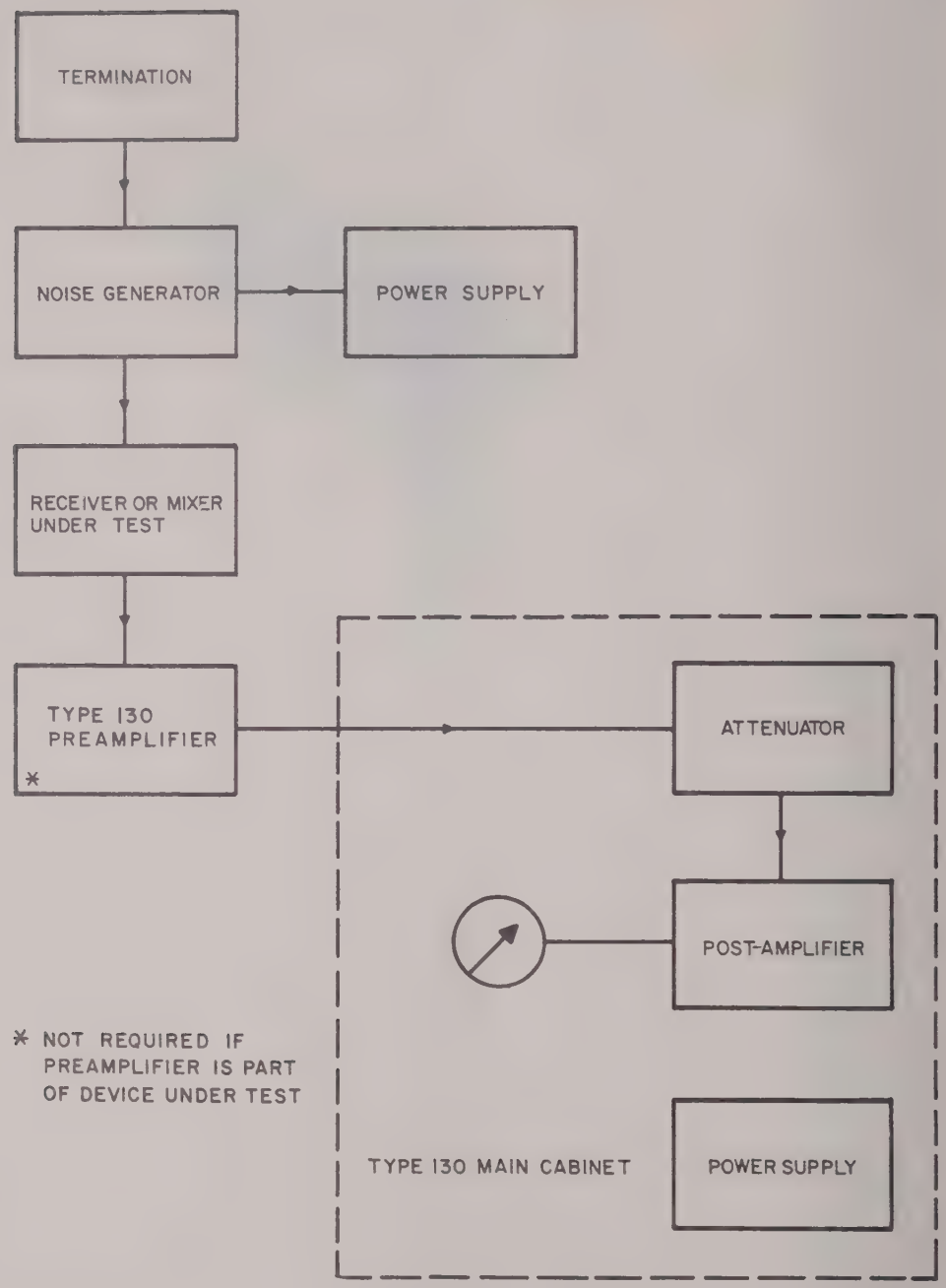


FIGURE 9. TEST SETUP FOR MEASUREMENT OF NOISE FIGURE

to 3 db (030) and adjust the noise-generator output to establish the initial condition. The noise figure is then $F = 20IR$, where R is the generator impedance and I is the generator current for $Y = 2$.

IV. SCHEMATIC DIAGRAMS

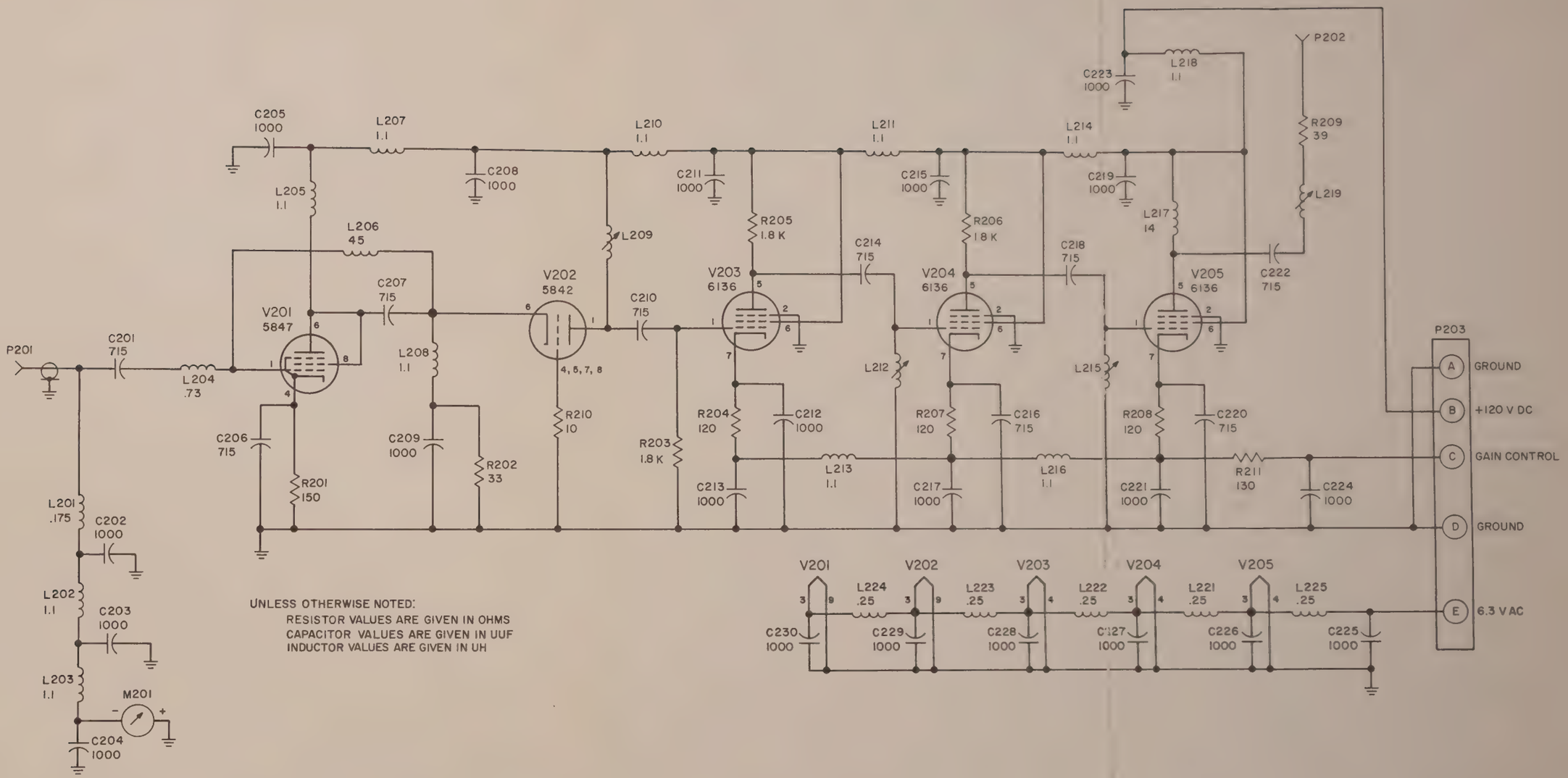
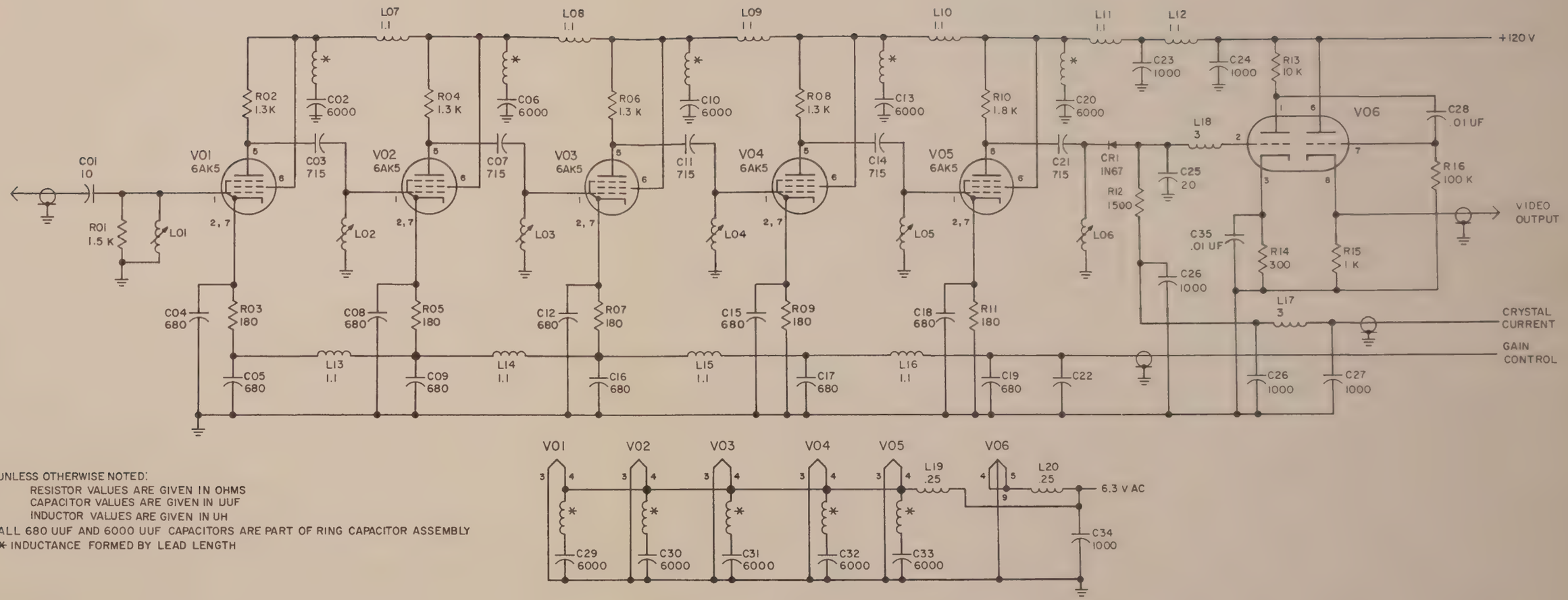
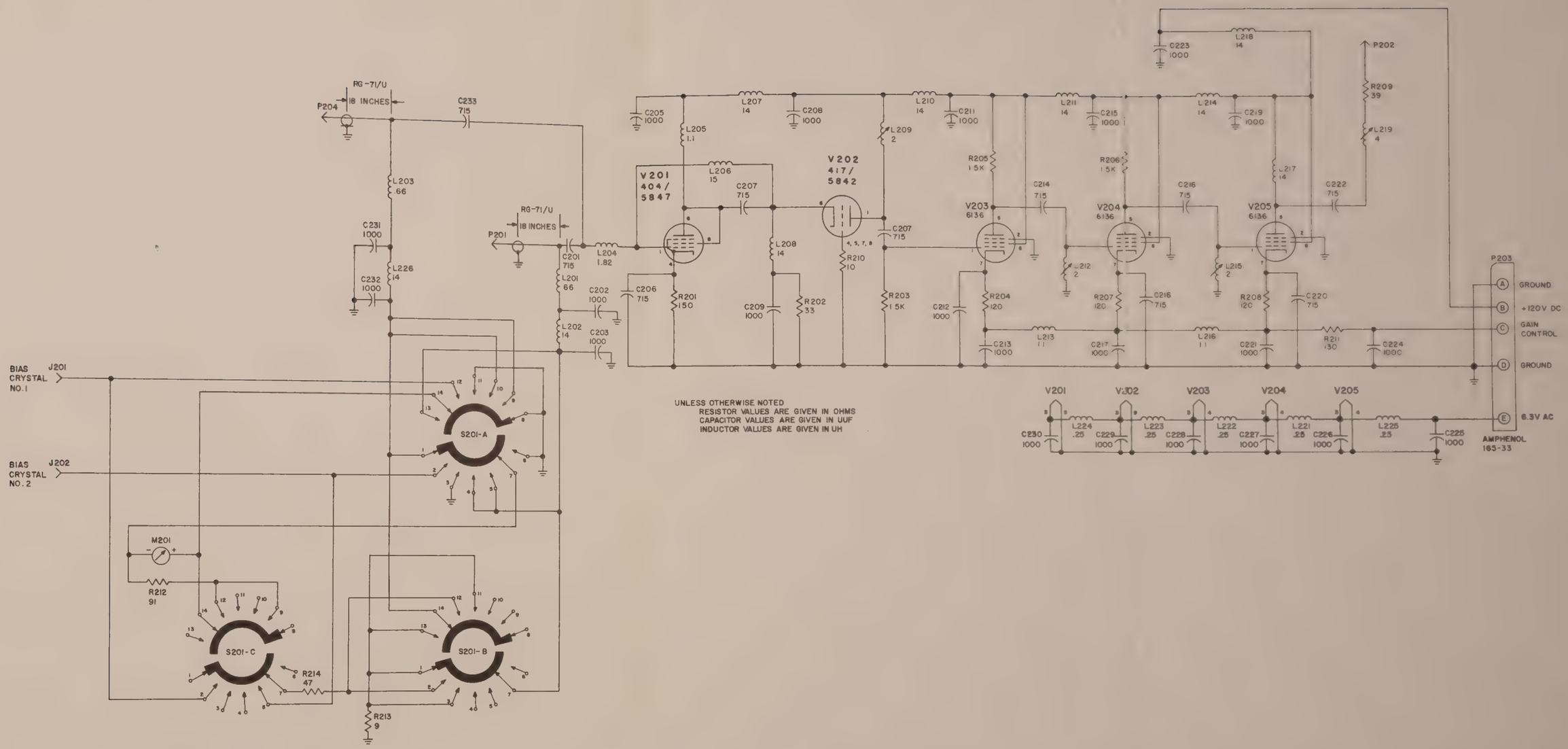


FIGURE 10. SCHEMATIC DIAGRAM OF 60-Mc PREAMPLIFIER



UNLESS OTHERWISE NOTED:
RESISTOR VALUES ARE GIVEN IN OHMS
CAPACITOR VALUES ARE GIVEN IN UUF
INDUCTOR VALUES ARE GIVEN IN UH
ALL 680 UUF AND 6000 UUF CAPACITORS ARE PART OF RING CAPACITOR ASSEMBLY
* INDUCTANCE FORMED BY LEAD LENGTH

FIGURE 11. SCHEMATIC DIAGRAM OF 60-Mc POST-AMPLIFIER



UNLESS OTHERWISE NOTED
RESISTOR VALUES ARE GIVEN IN OHMS
CAPACITOR VALUES ARE GIVEN IN UUF
INDUCTOR VALUES ARE GIVEN IN UH

FIGURE 12. SCHEMATIC DIAGRAM OF 30-Mc PREAMPLIFIER (DUAL UNBALANCED)

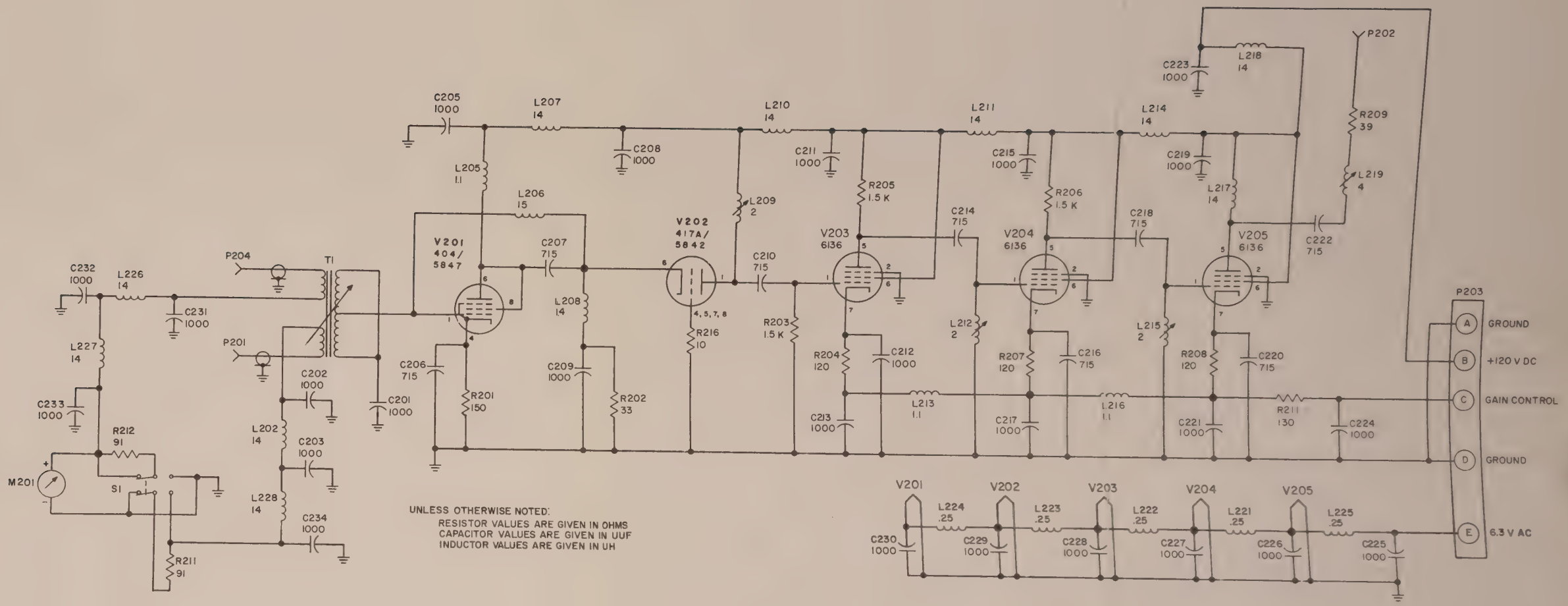


FIGURE 13. SCHEMATIC DIAGRAM OF 30-Mc PREAMPLIFIER (DUAL BALANCED)

APPENDIX

GENERAL DESCRIPTION OF MODEL 29-718 POWER SUPPLIES

1. GENERAL DESCRIPTION

The power supplies described herein are designed for use in industry, laboratory, radio station, and school to supply power to electronic and other equipment. The DC output voltage is electronically regulated and is practically independent of external load (within limits) and normal line voltage fluctuations, and is also substantially free from hum and noise. Quality components, careful construction, and conservative ratings are used to ensure long and dependable service.

2. ELECTRICAL CHARACTERISTICS

Input	105 to 125 volts AC, 50 to 60 cps, 120 watts.
DC Output	Continuously variable from 100 to 200 volts DC regulated from 0 to 100 ma maximum. Either positive or negative side of supply may be grounded.
AC Output	6.5 volts AC at 3 amperes unregulated.
DC Voltage Regulation	Output constant to better than 1 percent for loads from zero to full load and line voltage variations from 105 to 125 volts.
Internal Impedance	About 10 ohms.
Noise and Ripple Output	Less than 5 mv rms for above ratings.
Tube Complement	5V4G rectifier, 2-6L6G series control tubes, 6SJ7 DC amplifier. OA3/VR-75 comparison voltage source, 6X5-GT rectifier.

3. MECHANICAL SPECIFICATIONS

Standard rack mounting	19 inches
Panel height	5-1/4 inches
Panel width	19 inches
Depth behind panel	7-1/2 inches
Weight	19 pounds
Panel finish	Black ripple enamel (standard)